Central Bank Balance Sheet Policies and Spillovers to Emerging Markets

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Abstract

We develop a theoretical model that shows that in the near future, the monetary policies of some key central banks in advanced economies (AEs) will have two dimensions—changes in short-term policy rates and balance sheet adjustments. This will affect emerging market economies (EMs), especially those that are pegged, as these EMs primarily use a single monetary policy tool, i.e., the short-term policy rate. We show that changes in policy rates and balance sheet adjustments in AEs may differ in their respective financial spillovers to pegged EMs. Thus, it will be difficult for EMs to mitigate different types of spillovers with a single monetary policy tool. We provide suggestions for additional tools (e.g., capital control and/or macro-prudential policy) for EMs to complement their monetary policy and financial stability toolkit. We also discuss how balance sheet adjustments that affect long-term interest rates may percolate to influence short-term interest rates via financial plumbing.

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GLOSSARY

AE: Advanced Economies
ASW: Araujo, Schommer and Woodford (2015)
CFM: Capital Flow Management
DTCC: Depository Trust and Clearing Corporation
EM: Emerging Markets.
EMB: Emerging Market Bonds.
FF: Federal Funds
FFR: Federal Funds Rate
FGP: Fostel, Geanakoplos and Phelan (2015)
GFC: General Collateral Finance
GSD: Government Securities Division
HK: Hong Kong
IOER: Interest on excess reserves
OTC: Over-the-Counter
QE: Quantitative Easing.
RRP: reverse repo purchase
SOMA: System Open Market Account
U.S. United States
UST: U.S. Treasuries.

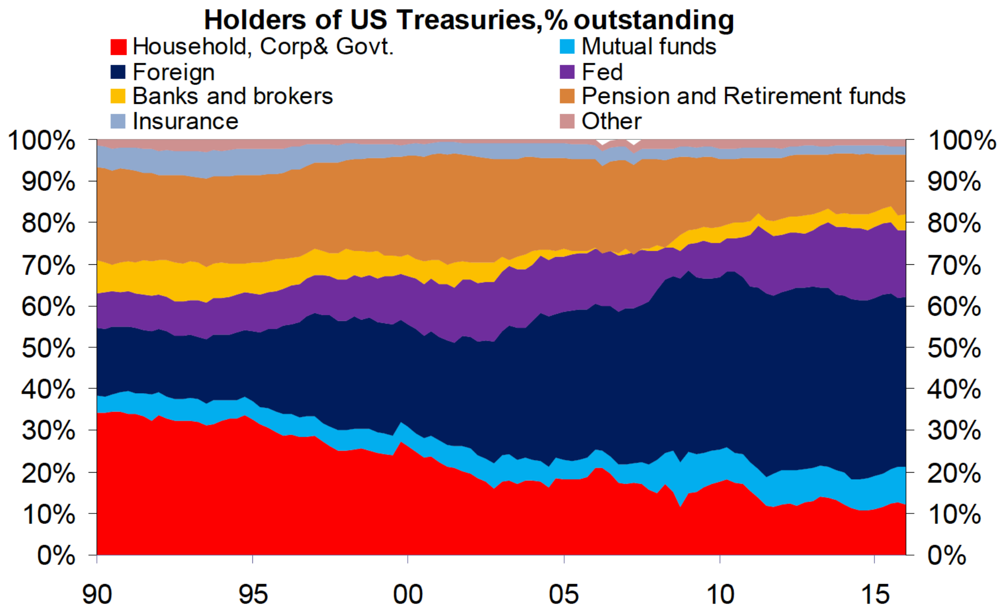
I. INTRODUCTION

Short-term policy rates in many advanced economies (AEs) have remained persistently low since the aftermath of the recent financial crisis. In an effort to manage sluggish economic recoveries and reinvigorate growth, several leading central banks (e.g., the Federal Reserve in the United States, and the Bank of England, and now the European Central Bank, and the Bank of Japan) have carried out several rounds of quantitative easing (QE) to provide further monetary stimulus. A lively empirical literature suggests that QE policies in AEs have generated spillovers to emerging market economies (EMs) in particular; this has raised concerns about the sharp increase in cross-border financial volatility. While the empirical evidence for QE's financial spillovers is well documented, the economic explanation of its international transmission remains relatively obscure. This paper provides a theoretical framework to study the financial spillovers of QE, and QE unwind to EMs. We show that conventional interest-rate policy and balance sheet adjustments consist of two independent dimensions of monetary policy in some AEs; furthermore, these two independent policy tools differ in their respective financial spillovers to EMs. We analyze the policy limitations EMs face in response to potential balance sheet adjustments in AE, and discuss possible policy options for EMs to complement such incomplete arrangements.

While QE's international spillovers can operate via many channels, this paper focuses on the collateral channel of transmission. In this context, the collateral channel is essential for two reasons. First, since the onset of QE, a large fraction of the assets acquired by AE central banks (e.g., U.S. Treasuries (UST)) has traditionally consisted of important collateral that facilitates collateralized cross-border funding. For example, international investors in AE government bonds obtain easy access to cross-border funding by pledging the underlying securities as collateral in the repo, securities lending, prime brokerage, and derivatives markets. The collateral properties of AE government bonds were further reinforced by the increased risk aversion and changing regulatory landscape that led to a growing demand for high-quality liquid assets (i.e., good collateral) after the financial crisis. Second, QE has involved massive purchases of this important collateral; thus, AE central banks' absorption of high-quality collateral from the private market has raised concerns about QE's potential disruption of the proper functioning of the collateral market.

As an example of AE government bonds, consider UST. Although estimates may vary, it is well-known that a large share of UST has always been held outside U.S. jurisdiction by foreign investors and central banks (see Figure 1). Furthermore, UST have traditionally been among the most widely accepted collateral in the cross-border funding market. Therefore, it is important to study how the Federal Reserve's balance sheet adjustments might interact with collateralized cross-border funding via the collateral channel.

Figure 1. Ownership of U.S. Treasuries



Source: Deutsche Bank

This paper develops a framework that features two countries—the U.S. and an EM—that differ in the collateral values of their assets.[2] Each country consists of private-sector agents and a central bank. Each country issues long-term government bonds denoted by UST and EMB (Emerging Market Bonds). All private borrowing must be secured by collateral, and, internationally, only UST can serve as collateral in the cross-border funding market.[3] The Federal Reserve not only has effective control over the short-term policy rate (consistent with conventional monetary policy), but can also engage in QE in the form of direct purchases of UST (financed by issuing riskless central bank reserves) to affect the long-term interest rate.

In our model, agents that face collateral constraints prefer UST over EMB, because UST can serve as collateral to obtain funding. Global demand for collateral and collateral-backed financial claims supports the collateral value of UST and results in its higher price relative to EMB, *ceteris paribus*. In equilibrium, UST enjoys a collateral premium over EMB. In our model, EM agents are subject to capital control in their purchases of UST.[4] The cross-border collateral property of UST may explain the continued global demand for UST in recent years.

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[2] We take the U.S. as an example of AEs for illustrative purposes. Our model is general and should apply to the situation between other AEs (e.g., the Eurozone) and EMs.

[3] Our assumption that all borrowing must be collateralized is for simplicity; it can be relaxed without affecting key results. For example, it could equally be assumed that only part of the private borrowing must be collateralized. Similarly, the assumption that only UST can serve as collateral can also be relaxed, so long as UST are assumed to have higher collateral value than EMB.

[4] An extension of the model suggests that removing capital control in EMs would further increase the collateral premium of UST.

Unlike private agents, the Federal Reserve can finance its asset purchases by issuing central bank reserves elastically without any collateral constraints.[5] This allows the Federal Reserve to raise the price of UST under binding collateral constraints. While global demand for collateral and collateral-backed finanical promises support the collateral value of UST, sufficiently large QE results in (i) a widening of international spreads and (ii) a subsequent portfolio shift by AE agents toward higher return EMB. This type of international portfolio shifts may weaken or even reverse the marginal effect of ever-larger QE interventions on the price of UST. In our model, while QE increases U.S. agents' relative holdings of EMB, EM demand for UST remains relatively stable (in response to QE) due to persistent EM demand for collateral.

An integral part of the paper is to study the unwind of QE and its implications for EM. Two scenarios are considered: (i) the AE central bank only adjusts the short-term policy rate (while maintaining its balance sheet) and (ii) the AE central bank unwinds its balance sheet by selling its UST holdings. Our analysis suggests that these two policies have different implications for EMs. In the former scenario, the EM central bank can mitigate financial spillovers by simply aligning its short-term policy rate with the AE central bank. In the latter case, however, there is no simple policy alignment with which EMs can offset cross-border financial spillovers and risks to financial stability. We use the model to illustrate how capital controls and macro-prudential policy might be viable complements in the latter scenario.[6]

Overall, our analysis suggests that many EMs, especially those that are pegged (e.g., Hong Kong and Gulf countries) or quasi-pegged like several countries in the Asian-dollar block (i.e., exchange rate is anchored against an AE like the U.S.), may need to assess their policy tools in response to cross-border financial spillovers. Our paper does not analyze EMs with flexible exchange rates. However, in the case of EMs with flexible exchange rate or inflation targeting regimes, exchange rate often remains important from a financial stability angle. Furthermore, EMs central banks have little control over their domestic yield curve (Naudon and Yany, 2016). Going forward monetary policy in some AEs may consist of two dimensions— a conventional policy rate as well as balance sheet adjustments. On the other hand, many EMs may continue to rely on a single monetary tool that mimics moves in AEs' short-term policy rates. The "Trilemma" postulation suggests that by giving up monetary independence and keeping short-term interest rates aligned with the anchor country, EMs can effectively achieve foreign exchange stability even under free capital flows. Our analysis suggests that with the use of balance sheet adjustments in AEs simply aligning the short-term policy rate will no longer be sufficient in shield EMs from external monetary spillovers. Balance sheet adjustment in AEs can create additional gaps in long-term interest rates, and trigger additional monetary and financial stability spillovers even when the short-term interest rates are well aligned.

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[5] Here the Federal Reserve, a financial intermediary, is capable of affecting asset prices because it is not subject to any collateral requirement, which represents a significant advantage over private financial intermediaries. Collateral requirement is a form of financial friction in the model, and, therefore, "Wallace Neutrality" does not hold.

[6] Although we use capital controls interchangeably with CFM (capital flow management), the IMF's institutional view considers CFM as a broader concept and comprises of residency based measures including taxes and regulations that impact cross-border financial activity. CFM also includes non-residency based measures that limit capital flows. [Macroprudential measures are designed to limit financial stability risks that are associated with capital flows].

The rest of the paper is organized as follows: Section II provides a brief literature review of previous work on the spillover effects of QE. Section III presents a two-country general equilibrium model with both conventional and unconventional monetary policies. Section IV presents major quantitative results from our model. We analyze different scenarios for the unwind of QE and discuss possible policy options for EMs seeking to counteract the associated financial spillover. In Section V we discuss the policy implications of our results and concludes.

II. LITERATURE REVIEW

Our paper is related to several strands of literature. The policy question we seek to explore stems from the vast empirical literature on QE's financial spillovers. Among many others, Fratzscher et al. (2011) analyze the spillover effects of QE in the U.S., and find that earlier phases of QE tend to have stronger effects on cross-border asset prices. They also find that capital flowed out of EM to the U.S. under QE 1, and went in the opposite direction under QE 2. Chen et al (2015) estimate both the financial and macroeconomic impacts of QE using a global vector error-correction model (GVECM). They find that QE in the U.S. has had more pronounced impacts on EMs than on other AEs; however, there is considerable heterogeneity across countries. Cho and Rhee (2013) conduct a panel analysis of QE's impacts on Asian economies and find that countries with more open and developed capital markets have experienced greater swings in cross-border inflows during QE episodes, while countries with more stable exchange rates tend to experience greater asset price inflation. Identification of QE's financial spillovers is generally challenging due to many other factors that can affect cross-border asset prices and capital flows, such as relative growth prospects, global risk aversion, etc., not to mention the associated endogeneity issue. (see, for instance, IMF WEO (2016 April) and Clark et al. (2016)). Nevertheless, empirical studies suggest sizeable cross-border spillover effects from AE's QE policies.

Despite abundant empirical studies, there has been limited theoretical work on QE's international transmission. Our two-country model builds on studies conducted by Araujo, Schommer and Woodford (2015), Fostel, Geanakoplos and Phelan (2015) and Wang (2016). In a single economy context, Araujo, et al. (ASW henceforth) develop a framework to study how the central bank's purchases of collateral-like assets might interfere with private agents' collateral constraints and impact asset prices. Fostel, et al. (2015) (FGP henceforth) develop a model that shows that financial integration can arise as a result of international sharing of scarce collateral. Wang (2016) builds on ASW and FGP to determine how the central bank's purchases of collateral-like assets might interfere with collateralized cross-border funding and subsequently generate financial spillovers. This paper extends Wang's model with a particular focus on QE's unwind and its implications for EM. This strand of work follows the collateral equilibrium models developed by Geanakoplos (1997) and Geanakoplos and Zame (2013), who focus on the effects of collateral on asset prices and real investment. As both studies demonstrate, much of the lending in modern economies is secured by some form of collateral, a feature that is often overlooked in conventional economic models.

We believe that collateral also plays an important role in QE's international transmission for three important reasons. First, much of the cross-border flows are secured via standard documentations such as global repo, derivatives, and securities lending agreements. Second, the bulk of assets involved in QE, such as UST, are traditionally important collateral that facilitate collateralized cross-border flows. Thus it is particularly relevant to understand how QE's absorption of high-quality collateral affects collateralized cross-border funding.

A recent report by the Bank of International Settlement reinforces the need to closely monitor monetary policy's impact on the collateral market.[7]

Lastly, our paper is also related to the growing literature that studies policy tools for EM seeking to mitigate external financial spillovers and improve financial stability. Forbes et al. (2015) exploit a novel propensity score matching methodology to study the effectiveness of capital flow management measures (CFMs) in achieving various policy targets. They find that certain macro-prudential policies are effective in improving measures related to financial fragility (e.g., bank leverage, bank credit growth, and exposure to foreign liabilities). Capital control is similarly found to be helpful in reducing private credit growth. Blanchard (2016) develops a two-country Mundell–Fleming model to study the impacts of AEs' macroeconomic policies on EMs' goods, foreign exchange, and financial markets. He concludes that capital control is more effective than foreign exchange intervention in achieving desired macroeconomic outcomes. IMF (2014), provides a discussion note on spillovers to EMs in the aftermath of the taper tantrum (i.e., gradual unwinding of Fed's QE program), in the summer of 2013. In particular, the paper highlights the high correlation between capital inflows to EMs, and Fed's QE program post the 2008 crisis. Furthermore, IMF (2015) highlights the institutional view and takes stock of both macroprudential and capital flow management measures, including definitional aspects, that may differ from the market's vocabulary.

This paper looks at the need for some EMs to use capital controls and macroeconomic tools to mitigate against balance sheet unwind of AEs central banks. However, there will be costs to EMs using such tools. Since the costs/benefits will be specific (and time-varying) to each EM, associated welfare analysis will be required to gauge the extent to which such tools will be implemented.

III. A Two-Country General Equilibrium Model with Collateral Constraints and Monetary Policy

We present a simple extension of the model in Wang (2016).[8] Consider a simple endowment economy with two countries: an AE and an EM. Time is discrete and there are two periods: t=0,1. There are two possible states in period 1: (U, D) where U stands for the "Up" state and D stands for the "Down" state. Agents in both economies consume a single consumption good C. Each economy has two kinds of government bonds. The first is a riskless nominal bond that is analogous to short-term government bonds such as Treasury bills and can be only issued by AE. The riskless nominal bond pays one unit of money in both U and D, and their payoffs (promises) will be paid by the government that issues them from tax revenues. For simplicity, we assume that there is a fixed exchange rate (equal to one) between the AE and the EM, and riskless nominal bonds are perfect substitutes across the two countries. Denote the riskless nominal bond as B.

The second type of government bond is a risky real bond and is analogous to long-term government bonds, whose payoff (e.g., par value) can vary across different states in the second period.[9] Denote the long-term government bonds in each country by (Y_{AE}, Y_{EM}). The

[7] Central Bank Operating Frameworks and Collateral Market, CGFS Publications No. 53.

[8] Readers can refer to Wang (2016) for more details about model setup of.

[9] We do not seek to model the maturity structure of long-term government bonds. Instead we focus on its riskiness (risk premium) relative to short-term government bonds.

payoff vectors of Y_{AE} and Y_{EM} are given exogenously by (d_U^{AE}, d_U^{AE}) and (d_U^{EM}, d_U^{EM}). Here Y_{AE} is analogous to UST, while Y_{EM} is analogous to EMB. A key distinction between Y_{AE} and Y_{EM} is that only Y_{AE} can serve as collateral to obtain collateralized funding in the cross-border market. [10]

A. Initial Endowment

There is a finite set of agents in both the AE and the EM, denoted by $\mathcal{H}$ and $\mathcal{H}^*$ respectively. Agents in each country are endowed (e) with period-0 consumption good for AE ($e_{C_0}^h$) and EM ($e_{C_0}^{h^*}$) respectively; and their respective risky bonds Y_{AE} for the AE agent (or, $e_{Y_{AE}}^h$), and Y_{EM} ,for the EM agent ($e_{Y_{EM}}^{h^*}$); and a riskless short-term government bond B that can only be issued by AE; and period-1 consumption good C, written as the following:

$(e_{C_0}^h, e_{Y_{AE}}^h, e_B^h, \{e_{C_s}^h\}_{s\in\{U,D\}})$ for $h \in \mathcal{H}$.

$(e_{C_0}^{h^*}, e_{Y_{EM}}^{h^*}, e_B^{h^*}, \{e_{C_s}^{h^*}\}_{s\in\{U,D\}})$ for $h^* \in \mathcal{H}^*$.

All notations with asterisk * denote variables for the EM.

B. Privately Traded Financial Contract

Agents can borrow from one another in the form of issuing financial claims. Denote the set of feasible financial claims by J. A financial claim $j \in J$ specifies the nominal repayment (j_U, j_D) in both states (U, D), and the amount of collateral Y_{AE} required to secure the contract. For simplicity assume that all financial claims are non-contingent so that $j_U = j_D = j$. Further assume each unit of financial claim must be secured by one unit of Y_{AE}. A unit of financial claim j can therefore be written as $((j,j); \textit{one unit of } Y_{AE})$. Denote the price of one unit of financial claim j by q_j.

Therefore, an agent can borrow q_j units of money in period 0 by issuing/selling a unit of financial contract j. The agent effectively promises nominal repayment (j,j) in period 1 and needs to own one unit of Y_{AE} as collateral to back his financial promises. Agents can buy or sell arbitrary quantities of a given financial claim at its competitive per unit price.

As in Geanakoplos and Zame (2014), agents cannot be coerced into honoring their promised repayment except by seizing the collateral used to back the financial contract. Therefore, the actual delivery of one unit of financial claim j in period-1 would be: min $\{j, p_s d_s^{AE}\}$, where $p_s d_s^{AE}$ [11] represents the value of the collateral. Denote the amount of financial claim $j \in J$ *purchased* by agent h by ψ_j^h and the amount of financial claim $j \in J$ *issued* by agent h by φ_j^h.

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[10] As mentioned in footnote 3, the assumptions here are for simplicity and can be relaxed without changing our key results.

[11] We assume that one unit of Y_{AE} delivers d_s^{AE} units of consumption good in state s of period 1. p_s is the price of the consumption good in state s.

C. Monetary Policy Specification

We assume the existence of a central bank in AE that can implement QE in the form of purchasing risky bond Y_{AE} by issuing riskless and interest-bearing central bank reserves. Interest payment on central bank reserves determines "the" riskless rate of return in the economy and represents conventional interest rate policy in our model. The amount of Y_{AE} acquired by the AE central bank is denoted by y_{AE}^{CB}. As in ASW (2015), we assume that the AE central bank here is a monetary-fiscal authority and is obligated to collect taxes in period 1 (i.e., the terminal period) in order to retire all public debt and reimburse/make up for any earnings/losses from its asset purchases.

Since this is a finite-horizon model, the AE central bank must specify the value of money (in terms of the consumption good) in the terminal period. This is necessary in order to pin down expectations about the real value of the interest rate i, the AE central bank promises to pay in period 1. We assume the AE central banks are able to fix the price of the consumption good in period 1 at $\{p_s\}_{s\in\{U,D\}}$.

Lastly, as mentioned earlier, we assume that there is a fixed exchange rate equal to one between the AE and the EM, and by default this implies that $i = i^*$. We do not consider the EM central bank's asset purchases in this paper.

Therefore, the complete monetary specification in the economy can be written as follows:

$$(i, b^{CB}, y_{AE}^{CB}, \{p_s\}_{s\in\{U,D\}})$$

A more detailed explanation on the general model setup can be found in ASW (2015) and Wang (2016).

D. Agent Maximization for the Advanced Economy (AE)

$$\max_{c^h\geq 0, \psi^h\geq 0, \varphi^h\geq 0, \mu^h\geq 0, y_{AE}^h\geq 0, y_{EM}^h\geq 0} u^h(c^h) \quad s.t.$$

$$p_0 c_0^h + \sum_{j=1}^{J} q_j(\psi_j^h - \varphi_j^h) + \pi_{AE} y_{AE}^h + \pi_{EM} y_{EM}^h + (1+i)^{-1}\mu^h \leq p_0 e_{C_0}^h + \pi_{AE} e_{Y_{AE}}^h + (1+i)^{-1} e_B^h, \tag{1}$$

$$p_s c_s^h \leq p_s\left(e_{C_s}^h + y_{AE}^h d_s^{AE} + y_{EM}^h d_s^{EM}\right) + \sum_{j=1}^{J}(\psi_j^h - \varphi_j^h)\min\{j, p_s d_s^{AE}\} + \mu^h - \theta^h(\mu - p_s y_{AE}^{CB} d_s^{AE}),\ \forall s \in \{U, D\} \tag{2}$$

$$y_{AE}^h \geq \sum_{j=1}^{J} \varphi_j^h, \tag{3}$$

where $p = (p_0, \{p_s\}_{s\in\{U,D\}})$ are the prices of consumption goods in each state of the world; $q = \{q_j\}_{j\in J}$ are the prices of financial contracts in J; $\pi = (\pi_{AE}, \pi_{EM})$ are the prices of (Y_{AE}, Y_{EM}); μ^h denotes each household's total holding of riskless assets, including both riskless short-term government bond and riskless central bank reserves [12]; $\mu = \sum_{h=1}^{\mathcal{H}} \mu^h$ is the total outstanding public debt (riskless government bonds and central bank reserves); and θ^h is the tax share of agent h.

Equation (1) represents agent h's period-0 budget constraint, which says that the expenditure on consumption + expenditure on asset portfolio $(\psi^h, \varphi^h, \mu^h, y_{AE}^h, y_{EM}^h)$ cannot exceed the total value of initial endowment. Note that when the term $\sum_{j=1}^{J} q_j(\psi_j^h - \varphi_j^h) \geq 0$, agent h is a net buyer of financial claims and effectively a lender. When $\sum_{j=1}^{J} q_j(\psi_j^h - \varphi_j^h) \leq 0$, agent h is a net issuer/seller of financial claims and effectively a borrower.

Equation (2) represents the budget constraint in state 's' of period 1, which says that the expenditure on consumption cannot exceed the value of consumption endowment + payoff from y_{AM}^h *and* y_{EM}^h + net delivery of financial contracts + payoff from riskless assets − tax obligation.

Equation (3) represents the collateral constraint, which states that agent h is required to hold sufficient Y_{AE}^h as collateral to back his total issuance of financial claims.

Agent maximization in the EM is the same as in the AE except that EM agents are subject to capital control and macro-prudential restriction in their purchases of AE assets. Raising τ [13] is analogous to a tightening of capital control, while raising k is analogous to tightening of the collateral requirement, and vice versa.

E. Agent Maximization for the Emerging Markets (EM)

$$\max_{c^{h^*}\geq 0, \psi^{h^*}\geq 0, \varphi^{h^*}\geq 0, \mu^{h^*}\geq 0, y_H^{h^*}\geq 0, y_F^{h^*}\geq 0} u^{h^*}\left(c^{h^*}\right) \quad s.t.$$

capital control parameter

$$p_0 c_0^{h^*} + \sum_{j=1}^{J} q_j(\psi_j^{h^*} - \varphi_j^{h^*}) + \pi_{AE}(1+\tau) y_{AE}^{h^*} + \pi_{EM} y_{EM}^{h^*} + (1+i)^{-1}\mu^{h^*} \leq p_0 e_{C_0}^{h^*} + \pi_{EM} e_{Y_{EM}}^{h^*} + (1+i)^{-1} e_B^{h^*}, \quad (4)$$

$$p_s c_s^{h^*} \leq p_s\left(e_{C_s}^{h^*} + y_{AE}^{h^*} d_s^{AE} + y_{EM}^{h^*} d_s^{EM}\right) + \sum_{j=1}^{J}(\psi_j^{h^*} - \varphi_j^{h^*}) \min\{j, p_s d_s^{AE}\} + \mu^{h^*} - \theta^{h^*}\mu, \ \forall s \in \{U, D\} \quad (5)$$

[12] As in ASW (2015), riskless short-term government bonds and riskless central bank reserves are perfect substitutes in the model.

[13] For simplicity, capital control here is only imposed on capital outflow from EMs. It can be similarly imposed on capital inflow to EMs and generates similar results. In fact, many EMs resort to capital controls asymmetrically. For example, India has capital control on outflows, but not on inflows; the equations/model account for this. (See Singh, 2007.)

macro-prudential parameter

$$y_{AE}^{h^*} \geq k * \sum_{j=1}^{J} \varphi_j^{h^*}, \tag{6}$$

F. Definition of Equilibrium

Given endowment and monetary specification:

$(e_{C_0}^h, e_{Y_{AE}}^h, e_B^h, \{e_{C_s}^h\}_{s\in\{U,D\}})$ for $h \in \mathcal{H}$;
$(e_{C_0}^{h^*}, e_{Y_{EM}}^{h^*}, e_B^{h^*}, \{e_{C_s}^{h^*}\}_{s\in\{U,D\}})$ for $h^* \in \mathcal{H}^*$;
and $(i, b^{CB}, y_{AE}^{CB}, \{p_s\}_{s\in\{U,D\}})$,

an equilibrium for the economy is a vector:

$$[(\bar{c}, \bar{\psi}, \bar{\varphi}, \bar{\mu}, \overline{y_{AE}}, \overline{y_{EM}}); (\overline{c^*}, \overline{\psi^*}, \overline{\varphi^*}, \overline{\mu^*}, \overline{y_{AE}^*}, \overline{y_{EM}^*}); (\bar{p}, \bar{q}, \bar{\pi})]$$

that is consistent with the monetary specification and in addition satisfies the following:

(i) Given prices $(\bar{p}, \bar{q})$ and interest rates (i), $(\bar{c}, \bar{\psi}, \bar{\varphi}, \bar{\mu}, \overline{y_{AE}}, \overline{y_{EM}})$ and $(\overline{c^*}, \overline{\psi^*}, \overline{\varphi^*}, \overline{\mu^*}, \overline{y_{AE}^*}, \overline{y_{EM}^*})$ solves AE and EM agents' maximization problem respectively.

(ii) $\sum_{h=1}^{\mathcal{H}} \overline{c_0^h} + \sum_{h=1}^{\mathcal{H}^*} \overline{c_0^{h^*}} = \sum_{h=1}^{\mathcal{H}} e_{C_0}^h + \sum_{h=1}^{\mathcal{H}^*} e_{C_0}^{h^*}$

(iii) $\sum_{h=1}^{\mathcal{H}} \overline{c_s^h} + \sum_{h=1}^{\mathcal{H}^*} \overline{c_s^{h^*}} = \sum_{h=1}^{\mathcal{H}} e_{C_s}^h + \sum_{h=1}^{\mathcal{H}^*} e_{C_s}^h + \sum_{h=1}^{\mathcal{H}} e_{Y_{AE}}^h d_s^{AE} + \sum_{h=1}^{\mathcal{H}^*} e_{Y_{EM}}^{h^*} d_s^{EM} \ \forall s \in \{U, D\}$;

(iv) $\sum_{h=1}^{\mathcal{H}} \overline{y_{AE}^h} + y_{AE}^{CB} + \sum_{h^*=1}^{\mathcal{H}^*} \overline{y_{AE}^{h^*}} = \sum_{h=1}^{\mathcal{H}} e_{Y_{AE}}^h$;

(v) $\sum_{h=1}^{\mathcal{H}} \overline{y_{EM}^h} + \sum_{h^*=1}^{\mathcal{H}^*} \overline{y_{EM}^{h^*}} = \sum_{h=1}^{\mathcal{H}} e_{Y_{EM}}^{h^*}$;

(vi) $\sum_{h=1}^{\mathcal{H}} (\psi_j^h - \varphi_j^h) + \sum_{h^*=1}^{\mathcal{H}^*} (\psi_j^{h^*} - \varphi_j^{h^*}) = 0 \ \forall j \in J$;

(vii) $\sum_{h=1}^{\mathcal{H}} \overline{\mu^h} = \mu \equiv \sum_{h=1}^{\mathcal{H}} e_B^h + (1+i)\pi_{AE} y_{AE}^{CB}$;

(viii) $\sum_{h^*=1}^{\mathcal{H}^*} \overline{\mu^{h^*}} = \mu^* \equiv \sum_{h^*=1}^{\mathcal{H}^*} e_B^{h^*}$ - $(1+i)\sum_{h^*=1}^{\mathcal{H}^*} \tau \pi_{AE} y_{AE}^{h^*}$

The model can be solved numerically as a system of non-linear equations. See Wang (2016) for further details regarding the solution of the model.

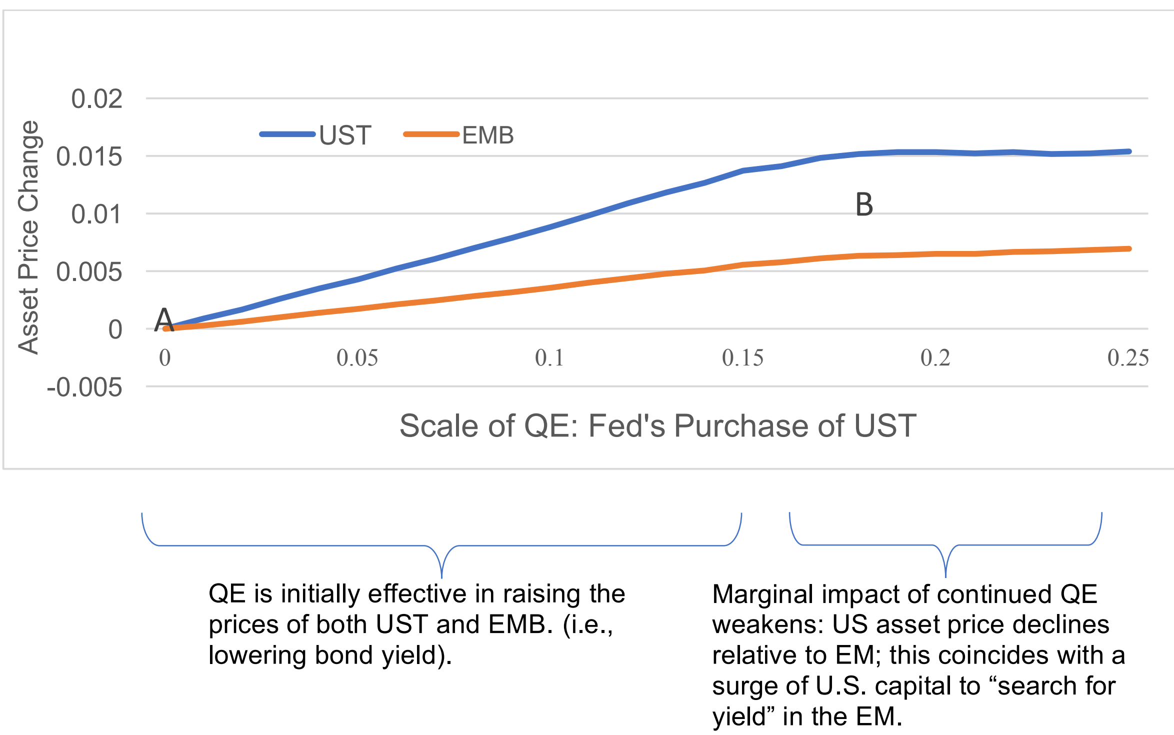
IV. Quantitative Results: Simulation and Empirical Evidence

This section presents our model's major quantitative results. We first show that with the introduction of QE, the AE central bank is able to directly affect the long-term interest rate (i.e., π_{AE}), despite keeping the short-term interest rate unchanged. This is illustrated in Figure 1.

Next, we show that with the holdings of Y_{AE} on its balance sheet, the AE central bank is able to deploy two dimensions of monetary policy during QE exit: (a) adjustment of the short-term policy rate and (b) adjustment of balance sheet holdings. We show that these dimensions of monetary policy in the AE differ in their financial spillovers to the EM. In the case of policy rate adjustment in the AE, the EM can counter financial spillovers by simply aligning its short-term policy rate with that of the AE central bank. However, in the case of a balance sheet adjustment (e.g., unwind) in the AE, there is no simple policy alignment for the EM.

Finally, we examine how policy options such as *capital control* and *macro-prudential tools* might be used by the EM to narrow the *changes* in long-term yield gaps, and thereby mitigate cross-border financial spillovers as a result of the AE central bank's balance sheet unwind.

Figure 2. Effects of QE on Asset Prices



Source: Authors' model estimates.

Figure 2 illustrates how QE affects the prices of UST and EMB in our model.[14] As the Federal Reserve starts purchasing UST, it creates excess demand for UST and initially results in its price increase relative to EMB. Note that changes in the price gap between UST and EMB reflects the changing "collateral premium" demanded by the market and reflects market tightness for collateral. The widening price gap between UST and EMB from point A to point B suggests tighter collateral constraints in the global market as a result of QE.

While global demand for collateral and collateral-backed financial claims supports the collateral value of UST, large enough QE results in a widening of international spread and a subsequent portfolio shift by AE agents toward higher return EMB (beyond point B). The outflow of agents from the AE to the EM gives rise to the "kink" in the price of UST (blue line)—i.e., a temporary decline in the price of UST relative to that of EMB.

An important policy implication from Figure 2 is that despite keeping the short-term policy rate unchanged, QE can independently affect long-term yield gaps between the two countries.[15] Without a policy response from the EM, these changes in long-term yield gaps will likely translate into increased cross-border volatility. Traditionally, the EM could counteract monetary spillovers from the AE by aligning the short-term policy rate with the AE central bank. However, there is no simple policy alignment by which the EM can mitigate changes in long-term yield gaps as a result of the AE central bank's balance sheet adjustment.

The quantitative results above illustrate the effects of QE in the model. Our next objective is to study the unwind of QE and its implications for the EM. More specifically, we illustrate how a policy rate hike differs from balance sheet unwind.

We first show how asset prices respond to an increase in the short-term policy rate in the AE. (Note that in our model, the AE central bank controls the short-term policy rate by adjusting its interest payment on central bank reserves.) As shown in Figure 3a, an increase in the short-term interest rate leads to a linear decline in the price of UST; this is because at the margin, the price of UST is primarily driven by leveraged investors who fund their purchase with collateralized borrowing.[16] Thus, a rise in the short-term interest rate results in higher borrowing cost for leveraged investors, which in turn lowers the price of UST linearly. In our model, the EM aligns its short-term policy rate with the AE by default (since we assume a fixed exchange rate, as noted in Section III).[17] Figure 3a suggests that the EM's simple policy alignment with the AE would ensure that the price change in EMB mimics that of the UST.

[14] The X-axis indicates the share of Y_{AE} acquired by the AE central bank through QE.

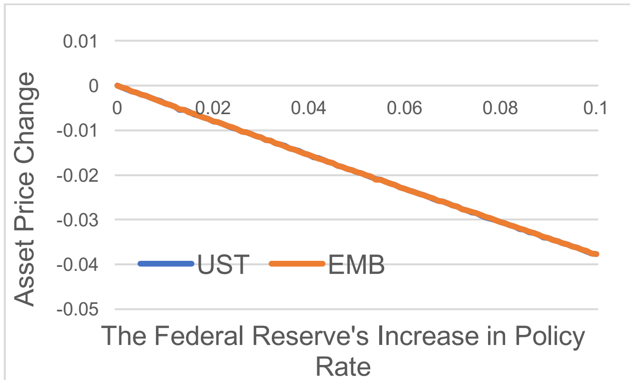
[15] The changes in the price gap between EMB and UST (i.e., $\pi_{EM} - \pi_{AE}$) are analogous to the changes in long-term yield gaps.

[16] Such investors include financial institutions that profit from maturity transformation, and other investors who borrow at the short-term rate and invest to earn the long-term term premium.

[17] As mentioned earlier, this is for simplicity since our focus is on the effects of unconventional monetary policy.

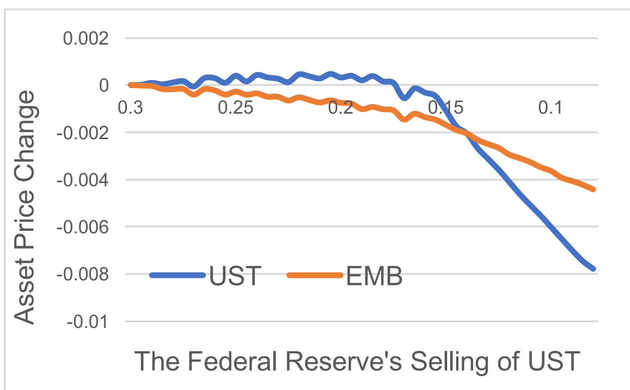
Figure 3. Policy Rate Change vs. Balance Sheet Unwind

Figure 3a. Effects of QE Exit: Interest Rate Hike
(Blue Line Overlaps with Red Line)



Source: Authors' model estimates.

Figure 3b. Effects of QE Exit: Balance Sheet Unwind



Source: Authors' model estimates.

Next, in Figure 3b we illustrate how asset prices might change if the AE central bank unwinds its balance sheet (i.e., by releasing UST back to the market) while keeping the short-term policy rate unchanged. In this case, it is worth noting that the Federal Reserve's release of UST back to the

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market does not result in an immediate decline in the price of UST. Instead, it remains robust initially as AE agents that invest in EM return to absorb the increased supply of UST (at higher yields) released by the AE central bank. This type of international portfolio shifts is accompanied by a slight decline in the price of EMB. The key difference between an interest rate hike and balance sheet adjustment is that the former only affects the asset price of UST, whereas the latter also alters the supply of UST.

Continued supply of UST eventually dominates the demand from returning investors, leading to a decline in the price of UST. The falling price of UST, meanwhile, expedites the decline in the price of EMB. In the case in which the AE central bank unwinds its balance sheet, there is no simple policy response by which the price changes in UST and EMB are aligned. Below, we show below how capital flow management and macro-prudential policies might be helpful in mitigating this kind of financial spillover.

Before we demonstrate how capital control and macro-prudential policy might help complement the EM's policy choices in response to the AE's balance-sheet unwind, it is helpful to discuss how the above results relate to the impacts of monetary policy on collateralized funding market in practice.

A. Uncertainty and Risks to the Value of Collateral

Our model suggests that a balance sheet adjustment by the Fed can directly influence the price of UST despite keeping the short-term policy rate unchanged. Given that UST is among the most prevalent collateral in the collateralized funding market, any increase in uncertainty or risks associated with the value of UST (collateral) can percolate through to the short-term interest rate in the collateralized funding market. For instance, if there are increased risks to the value of collateral (e.g., due to potential balance sheet adjustment by the Fed), lenders may demand a higher interest rate (or higher haircut) to compensate for the increased probability of default on collateralized contracts. Therefore, the Federal Reserve's impact at the long-end of the yield curve can also transmit to the short-end via such a collateral risk channel. Increased risks to, or uncertainty about the value of collateral as a result of QE unwind will likely have significant impacts on the collateralized funding market.

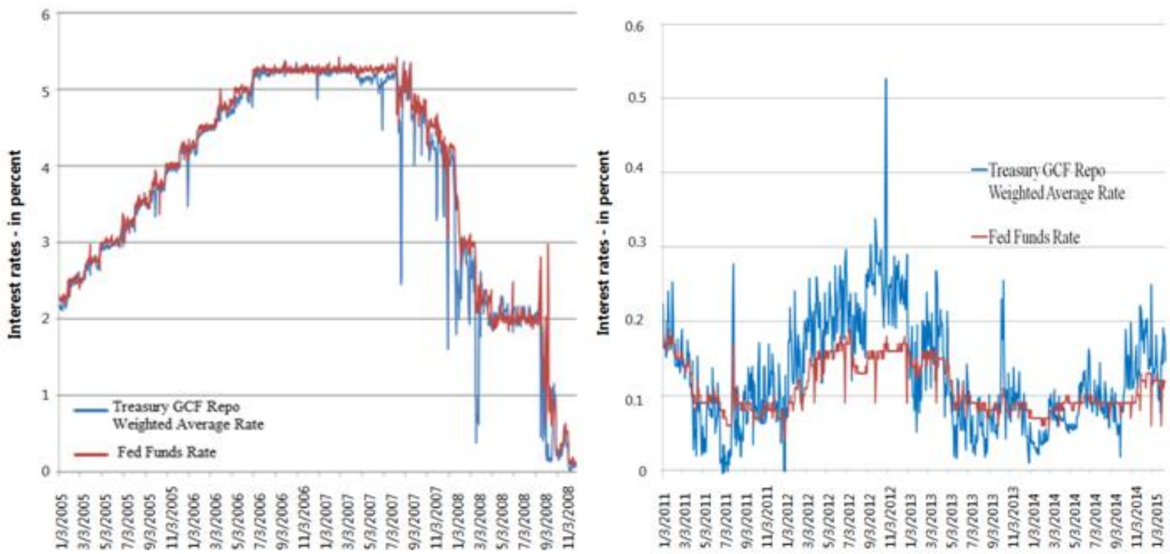
B. The Market Plumbing

Impacts at the long-end of the yield curve (as a result of balance sheet adjustment) can also percolate through to the short-term market rate via market plumbing, as Singh (2015) emphasizes. For instance, once the Federal Reserve's balance sheet unwinds and a 10 year UST is released to the market, it may not continue as a 10-year bond—the market could transform it into a one-month repo, a one-year repo, or a securities-lending transaction that has no defined tenor, or a margin towards an OTC derivative position; it could also be used for funding via rehypothecation to a prime broker. The collateral elasticity/velocity is exogenous to central banks; this results in "RRP (reverse repo program) type structures" that keep collateral velocity muted (Box 1). In the event that long-term UST are restructured and resold as short-term securities in the market, changes in long-term treasury yield will indirectly translate into changes in the short-term market interest rate. Such maturity transformation activities are, in fact, very common in the private market.

Bilateral pledged collateral market rates (via the bank/nonbank plumbing), although unobservable, do pass-through to other interest rates and thus, to the real economy. When the market plumbing works, the general collateral finance (GCF) rate is a reliable proxy for bilateral repo rates. Without the plumbing, the GCF rate would have little information content. After liftoff, it will be interesting to note whether the federal funds (FF) rate is in line with the GCF rate, as was the case pre-Lehman (see Figure 4). The FF rate remained within +/−3 basis points of the GCF rate, except for quarterly-ending dates that straddle inventory, regulatory, and reporting aspects.

Figure 4. Policy Rates and Market Short-term Rates
Pre-Lehman vs. Present (till liftoff)

(First panel: 2005–08; second panel: 2011–15)

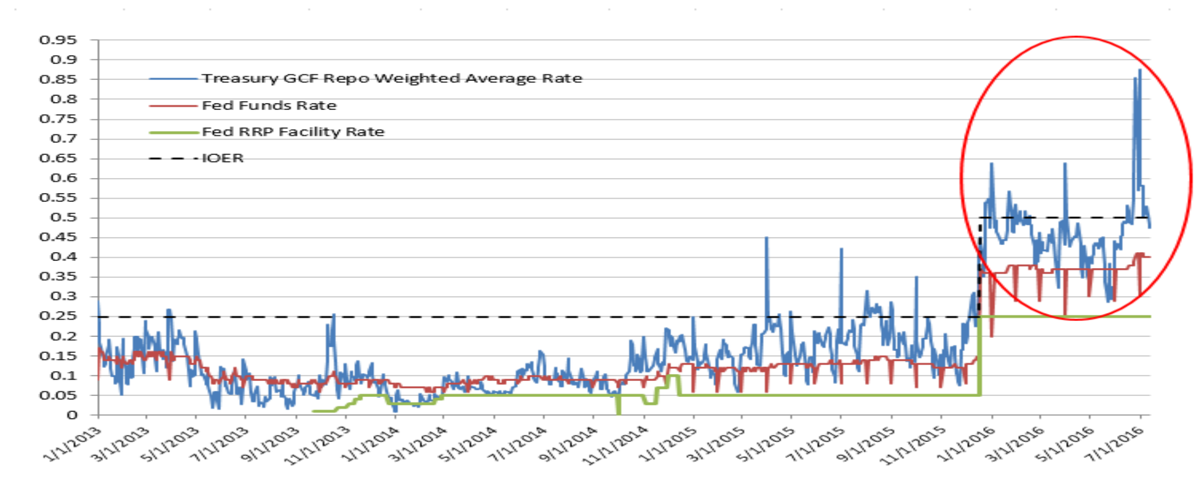


Sources: Depository Trust and Clearing Corporation (DTCC); Federal Reserve; and Bloomberg.

Due to QE, the Federal Reserve's balance sheet increased from roughly $1 trillion (end 2007) to over $4 trillion by end 2014, owing mainly to about $3.4 trillion of asset purchases that sit on its asset side. The approximate corresponding entry is excess reserves of $2.9 trillion on the liabilities side; these are deposits of nonbanks (that sold assets to the Federal Reserve) at banks, that then placed them as deposits at the Fed. From October 8, 2008 to December 16, 2015, the Federal Reserve offered banks 25 basis points per annum for their deposits (including excess deposits over the required reserves), but paid zero interest on deposits from nonbanks, especially GSEs.[18] Since liftoff, the Federal Reserve has offered 50 basis points to banks called interest on excess reserves (IOER), represented by the dashed line in Figure 4), and 25 basis points to eligible nonbanks via the reverse repo program (shown by the red line in Figure 4).

[18] To be precise, the total UST and MBS held by the Federal Reserve as of April 22, 2014 was $4.2 trillion, of which $750 billion were held as of end 2007. Excess reserves as of April 22, 2014 were $2.9 trillion, essentially all of which was added after end 2007.

Figure 5: After Fed liftoff: Spread between Repo Rate and Fed Funds has Increased



Source: Bloomberg and DTCC

The wedge between GCF and FF is relevant to policy makers. Should they continue to focus on the policy rate where volumes are shrinking to below $100 billion/day, and the rate itself is supported by the RRP floor and IOER ceiling? Neither existed prior to 2008. Or, focus on the GCF which is an approximation of market driven secured funding rate(s) (which we do not observe), and thus relevant for cross-border pledged collateral flows (of almost $6 trillion)?

Prior to the Lehman's crisis, there was generally a *shortage of reserves* that was met by the Federal Reserve's interventions from repo operations (via the relatively small "system open market account" (SOMA) at the New York Fed) so that the Fed Funds rate remained aligned with the collateral rate (i.e., GCF rate to be specific). Fast forward seven years and now there is an *excess of reserves* with the banking system so changes in the Fed Funds rate are not possible (see Box 1 and Box 2).[19] Looking at Figure 5, has the market shifted from a market in which secured GCF rates were in sync with policy rates, to where GCF is permanently higher?

Simon Potter, who heads the markets group at the New York Fed, remarked in his February 2016 speech on the lift-off (which was accompanied by increasing the RRP to about $2 trillion):

> *"One might also worry that money market rates might not move together as rates rise, meaning that, for example, a disconnect might emerge between secured and unsecured rates, or between overnight and term instruments. Either situation could result in impaired transmission of monetary policy into broad financial conditions."*

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[19] Larry Summers' recent remarks at the Annual IMF Research Conference (November, 2016) suggest that, "money, in the Friedman sense, no longer plays a significant role in macroeconomics"; "money is a hot potato and everyone tries to get rid of the hot potato"; and "money is equal to floating rate public sector debt."

Box 1. Fed's Liftoff and the Triparty Structure

Members of the Government Securities Division (GSD) of the Depository Trust and Clearing Corporation (DTCC) can reuse the collateral within the General Collateral Finance (GCF) triparty system. Here, we use the term "banks" very loosely; for example, Citibank could take collateral from the Fed and give it to a Fidelity mutual fund as a Triparty investment or it could take collateral from the Fed and give it in GCF to Credit Suisse to give to that Fidelity fund. To be clear, members of the GSD may be classified differently: Goldman Sachs is actually Goldman Sachs & Co.; Deutsche Bank is Deutsche Bank Securities Inc.; and Barclays is Barclays Capital Inc. Other members include Pierpont Securities LLC, Jefferies LLC, Cantor Fitzgerald & Co., etc. The important point is that reuse of collateral can only end in a Triparty repo; it can have no other use. Of the counterparties the Fed has taken on via the RRP, only the "banks" take on Triparty repo liabilities. The "released" collateral from the RRP remains as asset on the Fed's balance sheet and within the Triparty system.

The constraint noted above implies that, regardless of the size of the bids on RRP, the Fed's balance sheet will not decrease as a result of the "use" of excess reserves. The liftoff was accompanied by an increase in the RRP size of about $2 trillion. Even if used fully, this collateral will remain on the Federal Reserve's balance sheet and not be freely available to the financial system. Within the present Triparty structure, none of the collateral can be used to post at central clearinghouses, in the bilateral derivatives markets, in the bilateral repo market, or delivered against short positions—note, however, that a sizable pledged collateral market exists that is not constrained by a Triparty structure. Papers on this subject are generally silent on this aspect—i.e., that RRP is more akin to "*accounting drainage*" since the $3.4 trillion of assets purchased remain on the Fed's asset side, with RRP merely reshuffling line items on the liability side. Notably, a recent speech by the Fed actually includes RRP balances within the measure of excess reserve.[20]

There is a key difference between selling assets from the Fed's balance sheet in order to shrink the balance sheet, reshuffling Fed liabilities between line items called "excess reserves," and other items on the liability side such as RRP. Rearranging the Fed's liabilities gives rise to changes in someone else's balance sheet at every stage of the process; selling assets in contrast allows those assets to move directly to their final holder. For example: suppose the Fed sells UST to Goldman Sachs, which sells them to a hedge fund, which sells them to Bank of America (BoA), which sells them to an insurance company. The insurance company's balance sheet asset is a substitution of the securities for cash deposit at its bank—for example, BoA. In turn, both BoA's liabilities (the insurance company deposit) and assets (the Fed's reserve deposit) go down.

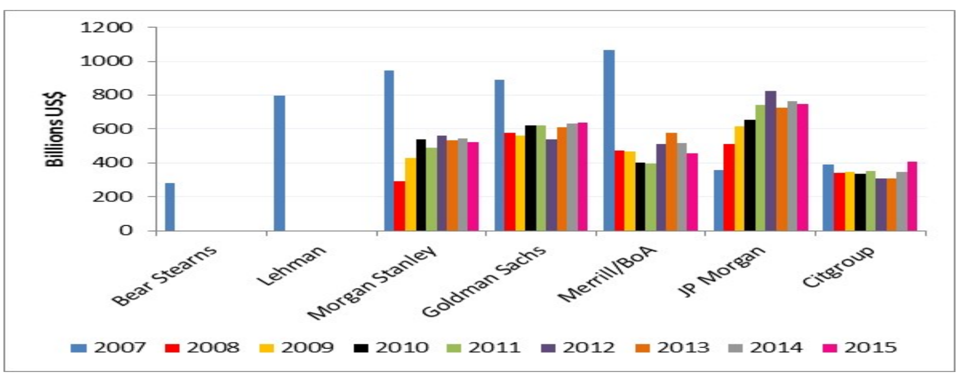
[20] http://www.ny.frb.org/newsevents/speeches/2015/pot150415.html (footnote 2).

Box 2. The Financial Plumbing: The Pledged Collateral (and its Reuse) Market

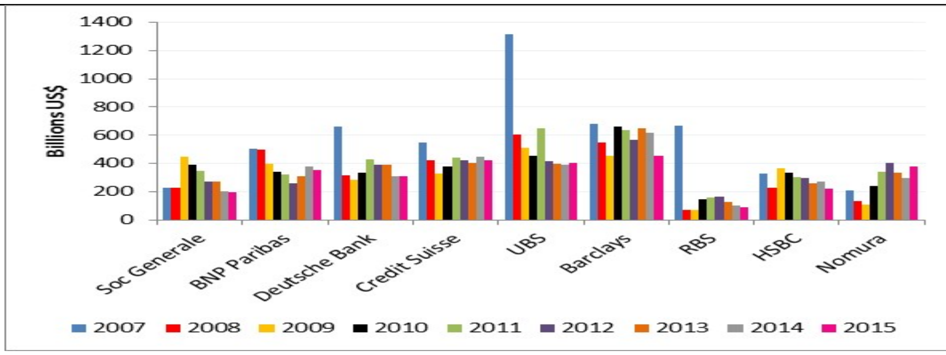
Financial agents that settle daily margins may post cash or securities, depending on which is "cheapest to deliver" from their perspective. These settlements form the core of the financial plumbing in markets that require debits/credits to be settled continuously. These securities are generally received by the collateral desks of the banks not only via reverse-repo but also from securities borrowing, prime brokerage agreements, and over-the-counter (OTC) derivative positions. The largest suppliers of pledged collateral are the hedge funds; other sources include insurers, pension funds, central banks, and sovereign wealth funds.

The "fair value of securities received as collateral that is permitted to be sold or re-pledged" by global banks was approximately $10 trillion in 2007 but has declined in recent years to about $5.6 trillion (see figures below). Before its decline, the pledged collateral metric was of the same order of magnitude as money metrics such as M2 in the U.S. or the Eurozone. Securities that are pledged, at mark to market values, may be bonds or equities, are cash-equivalent from a legal perspective (i.e., with title transfer) and do not have to be AAA/AA rated. The underlying economics of pledged collateral reuse are similar to reuse of deposits in the banking system (Singh and Stella, 2012). Following the methodology of Singh (2011), ESRB (2014), and DTCC (2014) and incorporating the amount of "source collateral," the collateral reuse rate (or collateral velocity) can be approximated, and has declined from about three as of end 2007 to about 1.8 as of end 2015. Central banks should be cognizant of the collateral reuse rate in the bilateral pledged collateral market, along with money metrics, to gauge the short-term rate environment, otherwise sales of good collateral (e.g., UST) with the reuse rate can result in short-term market rates having a large wedge with policy rates (e.g., Fed Funds).

Pledged Collateral Received by U.S. Banks (2007–15)



Pledged Collateral Received by European Banks and Nomura (2007–15)



Sources: Hand-picked data by authors from annual reports; see also Singh (2011).

C. Policy Options for EMs—Capital Control vs. Macro-prudential Policy

Although some economists (e.g., Bernanke (2015) and Greenwood, Hanson and Stein (2016)) argue that AE central banks can maintain their large balance sheet(s) and there may be no need to unwind it, it will be prudent for EMs to be equipped with the necessary tools in case the economy they are anchored to decides to unwind its balance sheet as part of its monetary policy.

As background, the Federal Reserve never remunerated excess reserves prior to the Lehman demise but began doing so on October 8, 2008 after changing the law. As the rate moves higher in the near future (well beyond the 25 basis points between October 2008 and December 2015), the Federal Reserve's remuneration on IOER paid to banks will be substantial and will likely raise social and political debates.[21] Furthermore, if policy makers believe that it is necessary for GCF to be in sync with FF, there must be a shortage of reserves in the banking system so that GCF can increase the supply of reserves to the banking system—a distant scenario from the approximately $3 trillion of excess reserves presently with the banking system. Only a genuine balance sheet unwinds (i.e., sale of assets) will reduce excess reserves.

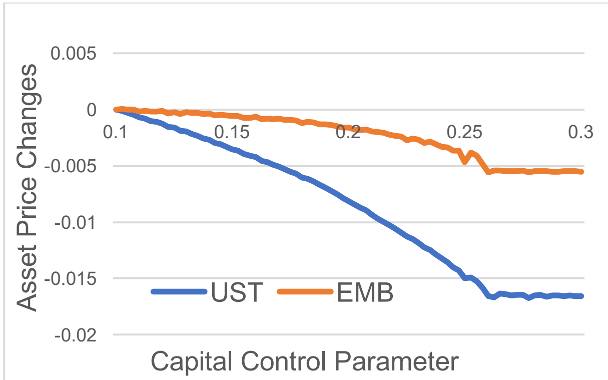
Figure 6a depicts the resulting asset price changes as the EM increases its capital control parameter. It shows that the EM's capital control puts a downward pressure on the price of UST relative to that of EMB. In other words, capital control in the EM is effective for strengthening the price of EMB relative to that of UST.

Similarly, Figure 6b, illustrates how asset prices respond to a tightening of macro-prudential policy in the EM. In our model, macro-prudential policy takes the form of an adjustment of the collateral requirement on agents. By raising the collateral requirement in the EM, leveraged investors are discouraged from purchasing of UST; this puts a downward pressure on the price of UST relative to that of EMB.

[21] The arithmetic of remunerating excess reserves is very different when policy rates are increasing; the envisaged cycle will be lower but consensus expects a 3 percent target (300 bps on $3 trillion is $90 billion; 25 bps on $3 trillion is $7.5 billion).

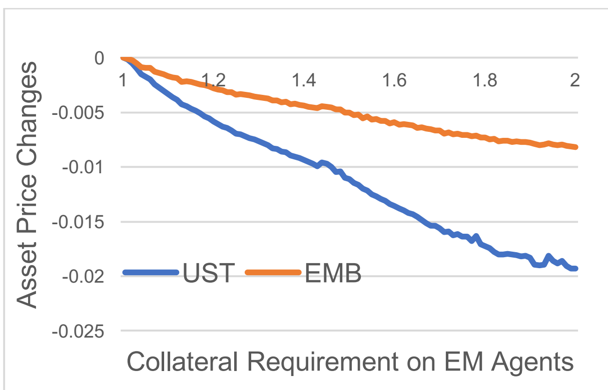
Figure 6. Raising Capital Control and Macro-Prudential Requirement Strengthens Relative Asset Price in EM

Figure 6a: Effects of EM's Capital Control



Source: Authors' model estimates.

Figure 6b: Effects of EM's Macro-Prudential Policy

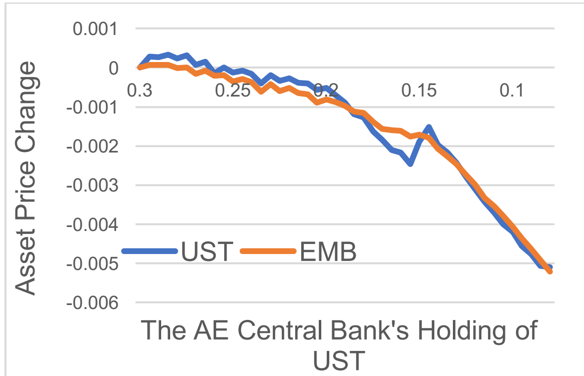


Source: Authors' model estimates.

As we can see, both capital control and macro-prudential policy in the EM strengthens the relative price of EMB against UST. We show that these two policy tools can be used to narrow the price gaps (as shown in Figure 3b) between UST and EMB.

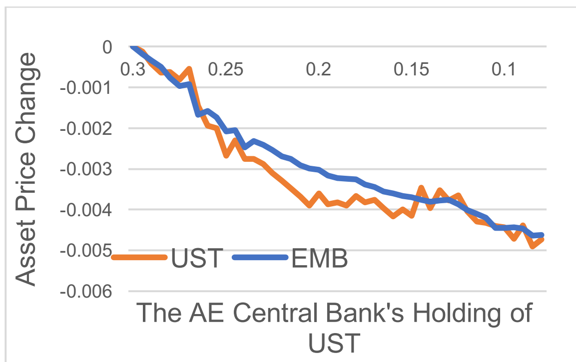
Figure 7. Capital Control and Macro-Prudential Response to Balance Sheet Unwind

Figure 7a: Varying Capital Control in Response to Balance Sheet Unwind



Source: Authors' model estimates.

Figure 7b: Varying Macro-prudential Policy in Response to Balance Sheet Unwind



Source: Authors' model estimates.

We vary the capital control parameter in an attempt to narrow the gap (in Figure 3b) between the price change of UST and EMB. Figure 7a suggests that by varying the intensity of capital control in the EM, it is possible to mitigate the price impact as a result of the AE central bank's balance sheet unwind. We adjust the capital control parameter so that it is positively correlated with the wedge (in Figure 3b) created by the AE central bank's balance sheet unwind; the capital control parameter is high (tightening) when the price gap between UST and EMB widens. Similarly, we show that macro-prudential policy can be implemented in a way that counteracts the effects of the Fed's balance sheet unwind, as shown in Figure 7b.

V. Conclusion

Going forward, several AE central banks will be able to exploit two major dimensions of monetary policy—the short-term policy rate and balance sheet adjustment. As demonstrated by our simple model, this allows for effective and independent control over both short-term and long-term interest rate. As a result, EMs that peg or soft-peg (i.e. exchange rate is anchored) to AEs may need to assess their policy framework and complement their financial stability toolkit (by including macroprudential and capital control measures).

We also show that understanding market signals such as repo rates is crucial since these have traditionally guided the policy rate (i.e., the FF rate). A normal liftoff assumes that all short term rates will move in line with the policy rate; otherwise, monetary policy transmission could be compromised. Although there has been no balance sheet unwind (see Box 1) since liftoff, the wedge between short-term rates is higher than the past. The crucial test will be when the Federal Reserve unwinds (i.e., conducts true asset sales); this could lead to a large wedge between short-term repo rates and policy rates since collateral velocity (i.e., the elasticity of collateral when released to the market) is not under the central banks' control.

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